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PARAGENETIC CLASSIFICATION OF THE MINERALS OF FRANKLIN, NEW JERSEY

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SUMMARY

A list is given of 137 species of minerals which are found in the region near Franklin, New Jersey. It is shown that these may be classified genetically into five groups of varying importance. Of the whole number of species, 111 are found in the zinc ore-bodies and 98 in these only; 13 are found in granite pegmatities; 18 in iron ores of pegmatic origin; 26 in the Pre-cambrian limestone and 5 in the Paleozoic limestone. These five paragenetic groups are described, those of less importance first and then the main group of the zinc-ore minerals. A paragenetic table for this group shows four main subdivisions viz:

1. Primary Ores: 2. Pegmatite Contact Minerals, (a) Skarns and Recrystallization Products; (b) Pneumatolytic Products: 3. Hydrothermal Vein Minerals: 4. Surface Oxidation Products.

Each of these groups is described with examples of characteristic mineral associations.

The origin of the zinc ores is discussed. The author's theory is that metasomatic deposits of hydrated oxides and silicates of iron, manganese and zinc were formed by replacement in the white limestone and that these ore-bodies were changed to their present mineral composition during the Pre-cambrian regional metamorphism simultaneously with the recrystallization of the enclosing limestone. Subsequent intrusions of pegmatites produced recrystallization of the primary minerals near contacts , and formed skarns by interaction of ores and magmatic materials. Pneumatolytic products of the pegmatite magma also reacted with the primary ores to produce numerous vein minerals and as the temperature fell hydrothermal veins of great variety were formed in the ore-body. These products of pegmatite intrusion are extremely diverse mineralogically but of minor importance compared to the great mass of the primary franklinite-willemite-calcite-ores.

The zinc mines of Franklin are located in the New Jersey Highlands, about fifty miles northwest of New York City. The region is readily accessible by three lines of railway and by excellent motor roads. There are two similar ore deposits, one on Mine Hill at Franklin (formerly known as Franklin Furnace), and the second about three miles southwest of Franklin, on Sterling Hill near the town of Ogdensburg.

The geological relations of the Franklin ore deposits have been described by A. C. Spencer in the Franklin Furnace Folio, No. 161, of the Geologic Atlas of the United States, published in 1908.

The characteristic rocks of the region are Pre-cambrian, probably Grenville in age, including limestone and gneisses of both sedimentary and granitic origin. With these are minor masses of granite pegmatite and a few basic dikes. Superposed upon this older series are stratified formations ranging in age from Cambrian (Hardyston quartzite) to Devonian (Kittatinny limestone) which are folded, faulted down into the Pre-cambrian and cut by dikes of probable Triassic age. Glacial deposits of various kinds mask the bed-rock geology of considerable areas.

In the Folio there may be found full details of the structure and composition of the ores and enclosing rocks, with maps and sections showing the distribution and form of the formations and ore deposits as known in 1908. Little has been published since regarding the geology and no detailed description has been given of the extensive mining developments of the last twenty years. But reference will be made to two papers by Ries and Bowen, and by Spurr and Lewis which contain important new facts. Their titles will be found in the references at the end of the paper.

The two main ore deposits are essentially alike in form and composition. Both are warped, tabular bodies with hookshaped outcrops. Both are wholly enclosed in the white limestone and their folds pitch to the northeast in sympathy with the general gneissic structure of the Highland region. In both the principal mineral constituents are four in number, franklinite, willemite, zincite and calcite; the first three being the ores of the metals zinc, manganese and iron for which the deposits are valuable, the fourth the sole important gangue.

Normally these minerals are intimately intermixed in granular form; the grains of the ore minerals are in general noticeably rounded and the interlocking calcite grains form a paste or matrix to the whole mass. Generally also a marked banding is visible in the mass of the ore, due to the greater or less concentration of one or more of the ore minerals in adjacent layers, parallel roughly to the walls of the deposit.

The mineralogical and chemical character of the average ore, established by long continued mill and assay tests, may be approximately stated in the following figures.

MINERALOGICAL COMPOSITION OF FRANKLIN ORE*

	Percentages
Franklinite	43
Zincite	1
Willemite	26
Other Silicates (garnet, rhodonite, etc.)	5
Calcite	25

CHEMICAL COMPOSITION OF FRANKLIN ORE

	Percentages
ZnO	31
FeO	25
MnO	10
SiO_2	9
$CaCO_3$	25

In contrast to the very simple mineral composition of the ore bodies as a whole stands the complexity of the following list of the minerals found at Franklin, shown in Table I. The chief purpose of this paper is to attempt to analyze this list so as to show the various genetic assemblages of which it is composed.

TABLE I

LIST OF MINERALS OF THE FRANKLIN REGION.

The significance of the letters following each name is as follows: A, Zinc Ores; B, Pegmatite; C, Iron Ores; D, White Limestone; E, Paleozoic Limestone.

Actinolite	A
Albite	A, E
Allacite	A
Allanite	B, C
Anglesite	A
Anhydrite	A
Anorthite	D
Apatite	A, B, C, D
Apophyllite	A
Aragonite	A
Arseniosiderite	A
Arsenopyrite	C, D
Aurichalcite	A
Axinite	
Ferroaxinite	C
Manganaxinite	A
Azurite	A
Barite	A
Barysilite	A
Bementite	A
Biotite	C
Bornite	A
Bustamite	A
Cahnite	A
Calamine	A
Calcite	A, D, E
Calcium-larsenite	A
Celestite	A
Cerussite	A
Chalcocite	A
Chalcophanite	A
Chalcopyrite	A
Chloanthite	A
Chlorophoenicite	A
Chlorite	A
Chondrodite	D
Clinohedrite	A
Clinozoisite	A
Copper	A
Corundum	D
Crocidolite	A
Cuprite	A
Cuspidine	A
Datolite	A
Desaulesite	A
Descloizite	A
Diopside	C, D
Dolomite	A, D
Edenite	D
Epidote	B, C
Epistilbite	A
Fluorite	A, D, E
Franklinite	A
Friedelite	A
Gageite	A
Gahnite	A
Galena	A, B, E
Ganophyllite	A
Garnet	A, B, C
Glaucochroite	A
Goethite	A
Graphite	D
Greenockite	A

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* The figures of the first column were kindly supplied by the New Jersey Zinc Company, with permission to publish them. The chemical composition was calculated from them and is not exact since much of the iron and some of the manganese are in the sesquioxide state.

Gypsum	A
Hancockite	A
Hardystonite	A
Hedyphane	A
Hematite	A, D
Hetaerolite	A
Heulandite	A
Hodgkinsonite	A
Holdenite	A
Hornblende	A
Hyalophane	A
Hydrohetaerolite	A
Hydrozincite	A
Ilmenite	D
Jeffersonite	A
Larsenite	A
Lead	A
Leucaugite	D
Leucophoenicite	A
Limonite	A
Löllingite	A
Magnetite	A, B, C, D
Malachite	A
Manganite	A
Manganophyllite	A
Manganosite	A
Marcasite	A
Margarosanite	A
Mcgovernite	A
Microcline	B, C
Millerite	A
Molybdenite	C, D
Muscovite	B
Nasonite	A
Neotocite	A
Niccolite	A
Norbergite	D
Pectolite	A
Phlogopite	C, D
Prehnite	A
Psilomelane	A
Pyrite	A, C, D
Pyrochroite	A
Pyrrhotite	D
Quartz	A, B, D
Rhodochrosite	A
Rhodonite	A
Roeblingite	A
Roepperite	A
Rutile	C, D
Scapolite	C, D
Schallerite	A
Schefferite	A
Serpentine	A
Siderite	A
Silver	A
Smithsonite	A
Sphalerite	A, B, E
Spinel	C, D
Stilbite	A
Sussexite	A
Svabite	A
Talc	A
Tennantite	A
Tephroite	A
Thomsonite	A
Thorite	B
Titanite	B, C, D
Tourmaline	D
Tremolite	A, D
Vesuvianite var. Cyprine	A
Willemite	A
Zincite	A
Zinc-schefferite	A
Zircon	B, C
Zoisite	B

Of the more than one hundred and thirty minerals composing this list, slightly more than one hundred are found in the zinc-ore deposits and nearly one hundred are found there only. In order to eliminate the groups of less importance and concentrate the discussion on the main issue, the associated mineral deposits of the region will be taken up first.

PEGMATITE INTRUSIONS

Granite pegmatite forms an important part of the Pre-cambrian complex, appearing both in extensive mapable areas and in dikes of moderate and small size. It is later than the gneiss and limestone, both of which it cuts; and some at least of the pegmatite is later than the zinc deposits. It is probable that the pegmatites continued to be intruded through a long period of time. Spurr and Lewis (2) have pointed out that in various places in the limestone, pegmatite dikes have been drawn out into lenses or even broken into isolated blocks; and that these blocks have reacted on their whole periphery with the surrounding limestone. It seems improbable that a degree of movement sufficient to dissect these dikes so effectively should not also have dislocated the ore-bodies which were close at hand but now show unbroken continuity. It seems more reasonable to suppose that the ore was introduced after the first pegmatite intrusions and their deformation. The later pegmatites cut the ore deposits and do not show extensive deformation.

The composition of the pegmatite is granitic, with relatively little quartz. It consists essentially of microcline, oligoclase and quartz with occasional accessory minerals including apatite, muscovite, titanite, epidote, allanite and much more rarely thorite and zircon. Magnetite is rarely wholly absent and may be dominant as described under the next heading. Galena and sphalerite are often found in minute grains in the pegmatite and are believed to be original constituents. Zoisite occurs as an alteration of microcline. At the contacts of pegmatite with both the limestone and the zinc ore-bodies groups of reaction and pneumatolytic minerals are generally developed which will be described under later headings.

MAGNETITE DEPOSITS

Magnetite in mineable bodies is found in various parts of the Franklin region. The magnetite ores occur in both limestone and gneiss and are so intimately associated with pegmatite that there can be little doubt of their genetic relation. It is noteworthy that zinc and manganese compounds are lacking in these iron ores although minute traces of both metals have been detected in the magnetite. The minerals composing the iron ores, most of them except magnetite present in small amounts or very locally developed, include magnetite, microcline, diopside, epidote, allanite, biotite, phlogopite, scapolite, iron-axinite, iron-garnet iron-spinel, apatite, pyrite, arsenopyrite, molybdenite, rutile, titanite and zircon. This association of minerals reflects the relationship to pegmatite shown in the field by the iron ores.

THE FRANKLIN LIMESTONE

The limestone is a coarsely crystalline rock, known commonly as the white limestone from its typical color. It varies in composition from a practically pure calcium carbonate to a magnesian carbonate with almost the proportions of dolomite, the variation being very irregular and not affecting its appearance or degree of crystallinity. Near the ore deposits the limestone becomes manganesian and weathers black. This limestone has been largely quarried as a flux both at Franklin and Sterling Hill and to the north at Rudeville so that it is well exposed and has been a fruitful collecting ground for mineral seekers. It is characterized by a group of minerals, all devoid of both zinc and manganese, which are unknown to, or extremely rare in, the zinc deposits. Sometimes these minerals are in close proximity to pegmatite bodies or more basic dikes which probably caused their formation by interaction; in a larger number of occurrences, however, the minerals are quite isolated in the limestone and either represent products of its recrystallization during metamorphism, or the presence of new elements introduced by the intrusives which have migrated far from their source.

The minerals found in the limestone at pegmatite contacts include amphiboles, chiefly tremolite and edenite; pyroxenes, especially diopside and leucaugite or aluminous pyroxene; scapolite; green and brown, magnesian tourmaline; chondrodite and norbergite, intergrown or separate. The writer has never seen garnet in the limestone away from the zinc ores although Spurr and Lewis (2) describe it from the wall of the ore body. It may be noted that except for pyroxene all the minerals of this group contain some "mineralizer" such as hydroxyl, chlorine, boron or fluorine, a condition which hardly agrees with the statement of Spurr and Lewis that these minerals are due to simple heat reactions without the presence of gas.

The minerals found in the limestone in isolated crystals or grains include all the foregoing and in addition graphite, molybdenite; chalcopyrite; pyrite; pyrrhotite; arsenopyrite; fluorite; quartz; corundum; hematite; ilmenite; magnetite; spinel; rutile; anorthite; phlogopite; titanite; and apatite.

This group of limestone minerals is typical for such highly metamorphosed limestones; it could be duplicated with very minor changes for the well known mineral occurrences of Orange County, N. Y., which are in the same band of Franklin limestone a score of miles to the north; and for many other limestones. It clearly owes nothing in its formation to the agencies which produced the ore bodies.

PALEOZOIC LIMESTONES

The Paleozoic sediments have not been notably metamorphosed or mineralized. They have, however, been intruded by dikes of camptonite and nephelite syenite; and have been profoundly faulted, both events probably to be assigned to Triassic time.

Spurr and Lewis (2) record "irregular subsequent impregnations of fluorite, arsenopyrite, pyrrhotite, sphalerite, galena, and many other minerals" associated with such a basic dike in limestone. In the limestone in a number of places are seen irregular cavities on whose walls are crystals of fluorite, quartz, calcite, albite and sphalerite.

These occurrences are of minor importance in the mineralogy of the region but are of interest as showing the presence of sulphide-bearing solutions during the post-paleozoic deformation. It is quite possible that to such solutions are due the small and infrequent veins of carbonates, quartz, pyrite and sphalerite which are found cutting the ore deposits and which will be described on a later page.

THE ZINC ORES

There remain for consideration the minerals found in the zinc deposits, by far the most important as they are by far the most numerous minerals of the whole list. The classification of these minerals into genetic groups here offered is of course hypothetical but seems to simplify the description. It should be stated that most of the conclusions here presented are based primarily on the study of hand specimens. No detailed examination of the ores in place has been made by the writer, nor so far as he is aware, by any geologist or mineralogist among the hundreds who have visited or written about these deposits.

The minerals will be grouped under the following four headings, it being clearly recognized that the groups merge more or less insensibly.

Minerals of the Zinc Ores

1. Primary Minerals
2. Minerals of the Pegmatite Contact Zones
   a. Reaction and Recrystallization Products—"Skarn"
   b. Pneumatolytic products
3. Minerals of the Hydrothermal Veins
4. Minerals resulting from Surface Oxidation, etc.

Table II exhibits these groups, each mineral being accompanied by its chemical formula in order the better to bring out the chemical nature of the groups.

1. PRIMARY MINERALS

The four minerals certainly to be regarded as primary are those that make up the great mass of the two ore bodies at Franklin and Sterling Hill. These are franklinite, willemite, zincite and calcite. The proportions in which they are present in the average ore have been stated on a previous page.

There are frequent wide departures from the average. Franklinite, alone or with calcite, may form large masses of ore. Zincite has been segregated in certain bands almost to the exclusion of the other minerals. Willemite is in rare cases the only ore mineral in the calcite gangue. But the typical ore is a banded mass of all four minerals in rather coarse grains. To these may be added tephroite as an occasional rare accompaniment of willemite, probably of primary nature.

The relative age of these ore minerals has been determined by Ries and Bowen (1) through the study of thin sections of the ores. They show that tephroite and willemite are oldest followed by franklinite and zincite, but with more or less overlap.

Of these minerals which are the main ores at Franklin, only tephroite and willemite have been found elsewhere and then only as subordinate constituents of manganese and zinc deposits. The exceptional mineralogical character of the deposits is convincing evidence of unusual conditions determining their deposition.

2. MINERALS OF THE PEGMATITE CONTACT ZONES

This group is the most complex of any found at Franklin and includes the greater number of those species peculiar to the locality.*

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* The following 24 minerals were first found at Franklin (*F*) or at Sterling Hill (*S*) and are as yet not known elsewhere:

cahnite	(F)
calcium-larsenite	(F)
chalcophanite	(S)
chlorophoenicite	(F)
clinohedrite	(F)
franklinite	(F, S)
gageite	(F)
desaulesite	(F)
glaucochroite	(F)
hancockite	(F)
hardystonite	(F)
hetaerolite	(F)
hodgkinsonite	(F)
holdenite	(F)
jeffersonite	(F, S)
larsenite	(F)
leucophoenicite	(F)
mcgovernite	(S)
roeblingite	(F)
roepperite	(S)
schallerite	(F)
sussexite	(F)
zincite	(F, S)
zinc-schefferite	(F)

In addition to these, margarosanite and nasonite, first found at Franklin are only known besides at Långban.

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There is unfortunately a great lack of detailed observations in the mines to support the conclusions drawn from the chemical nature of the minerals. But in that part of the Mine Hill deposit known as the Trotter Mine the relations were definite and conclusive.

It is clear that the intrusion of pegmatite produced local high temperatures which not only effected recrystallization of the primary minerals of the ore but initiated a vigorous interaction between the ore minerals and the magmatic constituents at and near the contacts. Moreover, the pegmatites were in some cases rich in volatile constituents which varied from place to place, and were capable of combining with the ore minerals in a variety of new compounds. These reactions apparently continued through a considerable period of falling temperature, merging ultimately with purely hydrothermal processes whose products are placed in a separate group.

The pegmatite contact minerals have been divided into two groups which are not sharply separable. One, for which the convenient Swedish mining term "Skarn" has been employed, includes silicates and oxides which are conspicuous, especially at Franklin by reason of their abundance and brilliant color. Most of them are direct reaction products between ores and the silica and alumina of the pegmatite. The second group is termed pneumatolytic for it includes mostly minerals in which magmatic volatiles are present or some metal clearly derived from the magma.

(2a) Skarn and Recrystallization Products

The skarn silicates as shown in the table, column 2, are chiefly characterized by the presence of zinc or iron or manganese or all three. Rhodonite* is particularly abundant at Franklin and may be seen in great masses crystallized against calcite. At Sterling Hill the principal skarn was composed of jeffersonite with gahnite. There too, roepperite was locally very abundant and a manganese hornblende was found in very large crystals. The cyprine variety of vesuvianite is found at Franklin intergrown both with pegmatite and with rhodonite. Hardystonite, known only from Franklin, seems to form a transition to the next group as it always contains traces of lead minerals.

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* Rhodonite is always zinc-bearing at Franklin and should be termed fowlerite in exact usage.

Often with the skarn and again in independent areas, the primary ore minerals occur in coarse aggregates or large, well-formed crystals. Franklinite in octahedrons or dodecahedrons up to six inches in diameter; willemite, particularly the manganese-rich variety troostite, in large stout hexagonal prisms a foot or more long; and zincite in broad plates as much as six inches across are examples of these recrystallizations. Their association with skarn indicates that they are related to the pegmatite intrusions. But there is often no visible relation with intrusives and in fact the most notable occurrence of this sort was found in the early workings at Sterling Hill where pegmatite is less abundant than at Mine Hill. In such cases local accumulations of water may have become an active solvent through heating due to remote intrusions.

In a few cases recrystallization seems to have been accompanied by a certain degree of breaking down of the original minerals. As examples may be noted the occurrence of manganosite, MnO, a molecule generally only present here in franklinite and in solid solution in the zincite; and hematite in the remarkable cube-like parting masses intergrown with franklinite which may be due to the separation during recrystallization of some of the iron of franklinite.

(2b) PNEUMATOLYTIC PRODUCTS

This group includes a great variety of minerals, chiefly silicates, in which some element is present not normally found in either ore or pegmatite. These "mineralizer" elements include hydroxyl, lead, chlorine, fluorine, boron, arsenic and sulphur. A number of metallic sulphides are placed in this group with considerable doubt. The mode of occurrence of these minerals is various; they may constitute irregular masses mingled with skarn minerals which they seem to replace; or again they fill very definite veins in ore or skarn, along whose walls more or less replacement of the older minerals has occurred. The detailed paragenesis is almost infinitely variable and but a few examples will be mentioned. The group is practically confined to Franklin.

During the early development of the Trotter Mine at Franklin a pegmatite was revealed notable for the presence of green microcline and allanite. About it at the surface was an abundance of garnet skarn, and throughout the mine rhodonite and manganese-axinite were very abundant. Niccolite and chloanthite occurred here in considerable masses mingled with sphalerite and purple fluorite.

The Parker Shaft, sunk near the north end of the Mine Hill deposit cut through great masses of garnet-rhodonite-axinite skarn, associated with which were many lead silicates. Here were first found nasonite, margarosanite, roeblingite and hancockite and with them the hydroxylsilicates leucophoenicite, clinohedrite, pectolite and prehnite. Fluorine appeared there in fluorite, cuspidine and apatite, and copper in the native form and in cyprine.

Much the same suite of minerals was found in the replacement veins containing the recently found lead silicates larsenite and calcium-larsenite.

Cahnite, a calcium boro-arsenate, was found in cavities of axinite or in veins with willemite, hedyphane and datolite or in open vugs in rhodonite veins.

Veins with the succession garnet-tephroite-willemite-barite-calcite seem to belong in this group. Hodgkinsonite and leucophoenicite, the latter especially apt to be associated with sussexite, are widespread both as replacement and vein minerals. Willemite in particularly fine, complex crystals is characteristic of the group and franklinite, when found in open veins, takes on a rare cubical habit.

The metallic sulphides of this group occur mostly in ill-defined masses apparently replacing normal ore. They rarely show any relation to pegmatite and may be of much later introduction. As typical examples of their grouping may be mentioned chalcocite, surrounding octahedrons of magnetite and separated from them by films of native silver; films of native copper and of native lead in axinite-willemite-barite veins; and granular aggregates of galena, chalcopyrite, bornite, pyrite, löllingite and sphalerite, alone or variously mingled. It should be said that these occurrences of sulphides are small and rare.

There is no sharp delimitation between the pneumatolytic veins and those of the next or hydrothermal group. Some minerals occur in both but in the latter there is less evidence of replacement in the walls, the veins being in general clearly fissure veins.

3. MINERALS OF THE HYDROTHERMAL VEINS

The complexity of this group is scarcely less than that of the last into which it shades by imperceptible gradations; on the other hand, however, it includes many occurrences obviously formed at lower temperatures, either at greater distance from pegmatite intrusions or at a later period of fissuring. The vein form is characteristic, the walls clean-cut, the fissure either wholly filled or open and crystal-lined.

The veins are generally small and of no great linear extent. A width of a few inches is the rule and many of them are mere seams, less than an inch wide. Thus, although in places very numerous, their total bulk is insignificant in comparison with the great mass of the ore bodies. Their most notable characteristic is extreme variability of mineral content.

Here also space permits the description of but a few of the very numerous examples supplied by collections.

As a typical example of the veins transitional between pneumatolytic and hydrothermal may be cited the paragenesis, garnet-leucophoenicite-gageite-clinozoisite-willemite-zincite-pyrochroite-calcite. A similar type is seen in the combination, hodgkinsonite-willemite-hetaerolite-calcite.

Rhodonite, friedelite, schallerite and mcgovernite are each found as the sole filling of numerous fissures. Friedelite is often followed by barite and calcite. Willemite is very common as a vein filling, especially the light green or white fibrous variety, low in manganese and highly phosphorescent. Zincite is only known in crystals from vugs in calcite veins while the form known as calcozincite is a mixture of granular zincite with fibrous calcite, generally coating slickensides in ore.

The arsenates hedyphane, allactite and holdenite are found in veins with calcite while chlorophoenicite occurs with gageite and acicular willemite.

The zeolites ganophyllite, and heulandite are found in veins with rhodonite or sulphides; the other zeolites of the list are minor vein minerals.

Sussexite is typically a vein mineral, its asbestiform fibres filling narrow cracks or coating slickensides in ore. It is closely simulated by veins of fibrous tremolite mixed with calcite.

Another type of vein very common at Franklin consists dominantly of some carbonate, often strikingly banded parallel to the walls. The filling may be calcite with or without fibrous willemite; sometimes it is siderite or an intermediate calcium-magnesium-iron carbonate; again rhodochrosite or smithsonite. Dolomite is the filling of a few veins with open vugs lined with crystals of dolomite, calcite, albite, quartz, or sphalerite and more rarely with millerite, marcasite or the oxides goethite, manganite or hematite. Pyrochroite and chalcophanite are also found in calcite veins. Aragonite coats cracks with radiating rosettes of needles.

Quartz in compact form, alone or with massive sphalerite or pyrite forms narrow, clean-cut veins and at times shows crystals on free surfaces. On the whole it is very rare at Franklin.

The parageneses calcite-sphalerite, and calcite-sphalerite-quartz-willemite-crocidolite are common and conspicuous vein formations. In fact it is in these veins alone that sphalerite appears in any noteworthy amount at Franklin if we except the mass described above at the Trotter Mine.

Bementite and the closely related manganese serpentine are not uncommon as vein fillings, alone or more commonly with a carbonate such as rhodochrosite or smithsonite.

It is highly probable that the carbonate and quartz veins carrying sulphides belong to the much later, post-paleozoic deformation as suggested in an earlier paragraph.

4. MINERALS RESULTING FROM SURFACE OXIDATION, HYDRATION, AND CARBONATIZATION

With one important exception this group of minerals is of minor interest at Franklin and Sterling Hill. Manganese serpentine forms pseudomorphs after silicates such as rhodonite; the nickel-rich genthite known as desaulesite has replaced niccolite and chloanthite at the Trotter Mine. Quartz, hematite and limonite form gossans on a few pyritic veins at Franklin and in the gossans of sphalerite veins there are found small amounts of calamine and hydrozincite. The ordinary copper oxidation minerals form about the rare copper sulphides and descloizite, cerussite and anglesite were the alteration products of galena in a pyroxene skarn at Sterling Hill.

The exception noted was so remarkable, however, that it requires special description. Reference is made to the great bodies of calamine which during the "seventies" constituted the chief zinc ore mined at Sterling Hill. They occurred in two deposits lying in the angle between the two legs of the vein and shown as mines on the map in the Folio. In 1906 their place was occupied by irregular conical excavations, apex down, separated by a wall of barren pegmatite. When mining began this part of the area was a shallow water course and mining reached a depth of more than forty feet below the original level. The bare limestone walls remained in 1906 just as they were left by the stripping operations and the detail of surface clearly indicated that they were solution surfaces, probably the result of long continued action by underground waters. These exposures have been long since caved by the modern mining at Sterling Hill and the Noble and Passaic Mines exist now only as names on the Folio map.

Mr. O. J. Conley, Superintendent of the Noble Mine in 1878, very kindly went over the ground with the author and described the deposit of which no contemporary account was published. According to him the calamine formed a layer directly on the limestone, six inches or a foot in thickness. The principal filling of the excavated mass was more or less fragmental, consisting of sand, clay, and limestone fragments with loose and broken crystals of franklinite, willemite, garnet and the like. All was much stained by iron and manganese oxides. Separating this loose material from the calamine layer on the north side of the pit was a layer up to four inches thick of a greasy black mud very rich in manganese, which was the cause of dangerous slides in the pit. On the south side, in a similar relation to the calamine were found the deposits of chalcophanite and hydrohetaerolite which were so characteristic for this locality. Magnificent specimens of this calamine are preserved in collections and almost all the specimens examined show a considerable amount of harsh, brown or yellow clay adhering to the under surface. The clay is rich in zinc and has been named vanuxemite.

The relations of these calamine deposits, as described by Mr. Conley, to the ore-bed sufficiently establish their secondary nature. There is, however, further direct evidence in the presence, among the fragmental materials from the pit, of crystals of willemite still preserving their form but wholly covered with manganese-stained needles of calamine; and of deeply corroded franklinite crystals, surrounded by and imbeded in calamine. These zinc and manganese deposits resulted from the destruction of a certain portion of the outcropping ore-bed, the products of solution being carried to a lower position where they replaced the limestone with the zinc silicate and zinc, iron and manganese hydrous oxides. The reason for describing this deposit at such length is that it seems to throw some light on the origin of the major deposits as will be shown in the next section.

ORIGIN OF THE ZINC-ORE DEPOSITS

The vexed question of the origin of these unique ore deposits has been often discussed and it is not proposed to attempt here a full treatment of the matter. In the paper by Ries and Bowen (1) already referred to there is an excellent summary of the various theories which have been proposed and this may well be reproduced with some comments.

Among the theories which have been advanced the following are outstanding:—

1. Igneous Injection. First offered by Rogers in 1840. Suggested by Spencer in the Folio in 1908 as the best alternative. Rejected by Ries and Bowen in 1922 on the ground that it would not account for the admixture with the ore minerals of grains of Franklin limestone. Advocated by Spurr and Lewis, in 1925, the ores being regarded as igneous veindikes of sulphide magma which have lost their sulphur by later oxidizing roasting at a temperature above that of fusion. How the required oxygen was supplied is not revealed.

To the author the best argument against the theory of igneous injection is the mineral and chemical character of the ores.

2. Sedimentary Deposition. The zinc ores are supposed to be contemporary with the enclosing limestone and to have been metamorphosed with it. First proposed by Kitchell in 1855 and maintained by the geologists of the New Jersey Survey as late as 1896. It is difficult to establish because there is no way of determining whether the banding of the ore is parallel to the original bedding of the limestone. Neither does it explain the structure of the Sterling Hill deposit as now developed.

3. Contact Metamorphism. First proposed by Nason in 1890 and advocated by Kemp in 1893 who misinterpreted the evidence of the then poorly exposed pegmatite intrusions. Rejected by Ries and Bowen on evidence similar to what has been given in preceding pages as to the intrusive relation of pegmatite to ore.

4. Deposition by Magmatic Waters by a Process of Replacement of the Limestone. This theory is accepted by Ries and Bowen, their only question relating to whether the replacement preceded or followed the folding of the limestone. They

believe that it preceded the folding and that the "primary minerals," willemite, franklinite and zincite were deposited directly as such in that order, from magmatic solutions

To the author the nature of the primary minerals is such as seems unlikely to have resulted from the action of magmatic solutions. In all cases known to him where zinc ores have indubitably been deposited by magmatic solutions it is the sulphide which is formed and the absence of sulphides is one of the marked features of these ores.

5. Author's Theory. It is believed that the ore bodies were metasomatic replacements formed in the limestone in Pre-Cambrian time before its regional metamorphism; that they were deposited near the surface under oxidizing conditions and probably consisted largely of the hydrous zinc silicate, calamine, together with hydrated oxides of iron and manganese, and perhaps carbonates of zinc and manganese. The depositing solutions are believed to have derived their metallic contents from the products of oxidation of a previously existent mass of mixed sulphides.

It is believed that these oxidized minerals were laid down in more or less well banded masses whose form may well have been determined by a preceding folding of the limestone which initiated structures and controlled the flow of the depositing solutions. The present minerals constituting the deposits are, on this theory, the result of dehydration and recrystallization effected during the profound and long continued metamorphism of the whole Pre-Cambrian system of rocks. Thus were impressed upon the minerals of the ore deposits the identical texture and structures of the enclosing limestone, so marked a characteristic. The established sequence in the age of the minerals, oxides following the silicate, seems entirely consonant with the suggested mode of origin.

The metasomatic deposition of these ore bodies was suggested to the writer by the descriptions of two deposits of zinc minerals having a related origin. The first of these is a small-scale illustration which has the advantage of being located on the spot–the calamine deposits at Sterling Hill, described on a previous page. There had been accumulated a rich ore deposit consisting of parallel bands of calamine, smithsonite, zinciferous clay and iron and manganese hydrates; the banding followed the walls of the cavity in the limestone by whose solution place for the new ore was formed. The source of this ore was the near-by franklinite-willemite mass; and the new ore was constituted in such a fashion that had it and the surrounding limestone been subjected to a vigorous and deep-seated, high-temperature metamorphism, there might well have resulted from its dehydration and recrystallization a new deposit closely analogous to the parent mass.

The second illustration is drawn from the published description of the well-known zinc deposits at Moresnet, Belgium. Here there are vast sphalerite replacement deposits in Paleozoic dolomites. These have undergone a profound oxidation; the soluble products have been transferred to the adjacent dolomite and have there accumulated in synclinal folds which halted the circulation. Extensive deposits consisting principally of calamine, with some smithsonite and limonite have thus been formed in bodies whose form, while determined in general by the structure of the dolomite, is independent in detail of anything except the solvent action of the depositing solutions. It does not seem unreasonable to think that in these Belgian deposits of desulphurized zinc and iron ores we have in all respects, except the absence of manganese, a good presentment of the New Jersey zinc ores before the great metamorphism.

This metasomatic hypothesis of ore implacement seems to account for the observed facts without essential conflict. The localization in the limestone is necessary, the duplication not remarkable. The form of the ore bodies may be quite independent of sedimentary structure. The pitching synclines are conformable in attitude to the general structure of the gneiss but how much of the folding may have been effected during metamorphism we have no means of determining. The hypothesis is indifferent in this matter since the original form of the deposits may have been anything from a simple layer to a mass whose form was not unlike what we now see. The identical texture of ore and country rock; the banding of the ore; the sudden transition from ore to barren limestone; the dying out of the ore along the strike, northwards at Mine Hill; the occasional occurrence of disseminated ore in the limestone within the fold at Sterling Hill; all these characters are satisfactorily accounted for by the suggested process. The chemical character of the ore is unusual chiefly in the association of zinc with both iron and manganese; but we know of metamorphosed metasomatic deposits of iron and manganese and the addition of the third metal marks simply an unusual set of original conditions of accumulation. The mineral composition is conformable to the theory; for willemite we have no comparable example, but franklinite is a spinel and therefore to be expected as a product of the assumed mode of formation. Light is thrown on the presence of zincite by Magnusson's (3) recent study of the Långban deposits where manganosite, MnO, and periclase, MgO with a trace of ZnO, are shown to have been formed from manganese and magnesium carbonates by a high-temperature metamorphism. So zincite may have been formed by the breakdown of smithsonite in these deposits.

The modifications which have affected the ore bodies after their primary crystallization in present form are relatively unimportant and have been sufficiently illustrated in the foregoing paragenetic study. The only clear evidence of direct introduction of magmatic materials is to be found in the contact zones about the pegmatites which were certainly far later than the ore deposits themselves.

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Discussion of the foregoing paper would be welcomed by the author and editor and any comments or criticisms received will be printed in a future number of the Journal.—The Editor.

DOUBLY TERMINATED QUARTZ CRYSTALS OCCURRING IN GYPSUM

W. A. Tarr, *University of Missouri.*

The specimens upon which this brief description is based were obtained by Mr. Cecil Carroll, a student in the University of Missouri, during the summer of 1927. At the suggestion of Mr. Walter D. Keller, one of his instructors, the specimens were given to the writer. The occurrence of doubly terminated quartz crystals in massive gypsum is so unusual that the following notes describing them have been prepared.

The material available for study consisted of about 100 loose crystals (See figure 1), and two hand specimens of the massive gypsum (alabaster), only one of which contained quartz crystals (Figs. 2 and 3). The locality where this material occurred is about one mile southwest of Acme, along the highway between Acme and Roswell, New Mexico. The crystals were found loose upon the outcrop of a gypsum bed. The fragment containing crystals was also a loose piece. The gypsum bed is in the Manzano series of red beds, which consists of alternating beds of gypsum (the individual beds of which rarely exceed 10 feet in thickness), red sandstone, and limestone. The stratigraphic position of the bed from which the specimens came is unknown.

The alabaster is fine-grained, and ranges in color from a salmon-pink, on what is assumed to have been a bedding plane surface, to a pale pinkish white, three-quarters of an inch from the surface. The coloring is not uniformly distributed in any portion of the specimen and has apparently been introduced into the gypsum, before the quartz. The color is due to very fine particles of hematite, and its distribution in the alabaster points to an introduction inward from the dark colored outer portion. It is probably that this darker side was adjacent to a red sandstone or shale member. The alabaster does not show any sand grains.

The quartz crystals range from .075 millimeter to two centimeters in length. A few single crystals are one centimeter long and four millimeters thick. Larger crystals occur in the lot, but they are either intergrown with other crystals, or have included others. In the one specimen of gypsum where the crystals are in place, the large clusters of crystals are found mainly in a zone

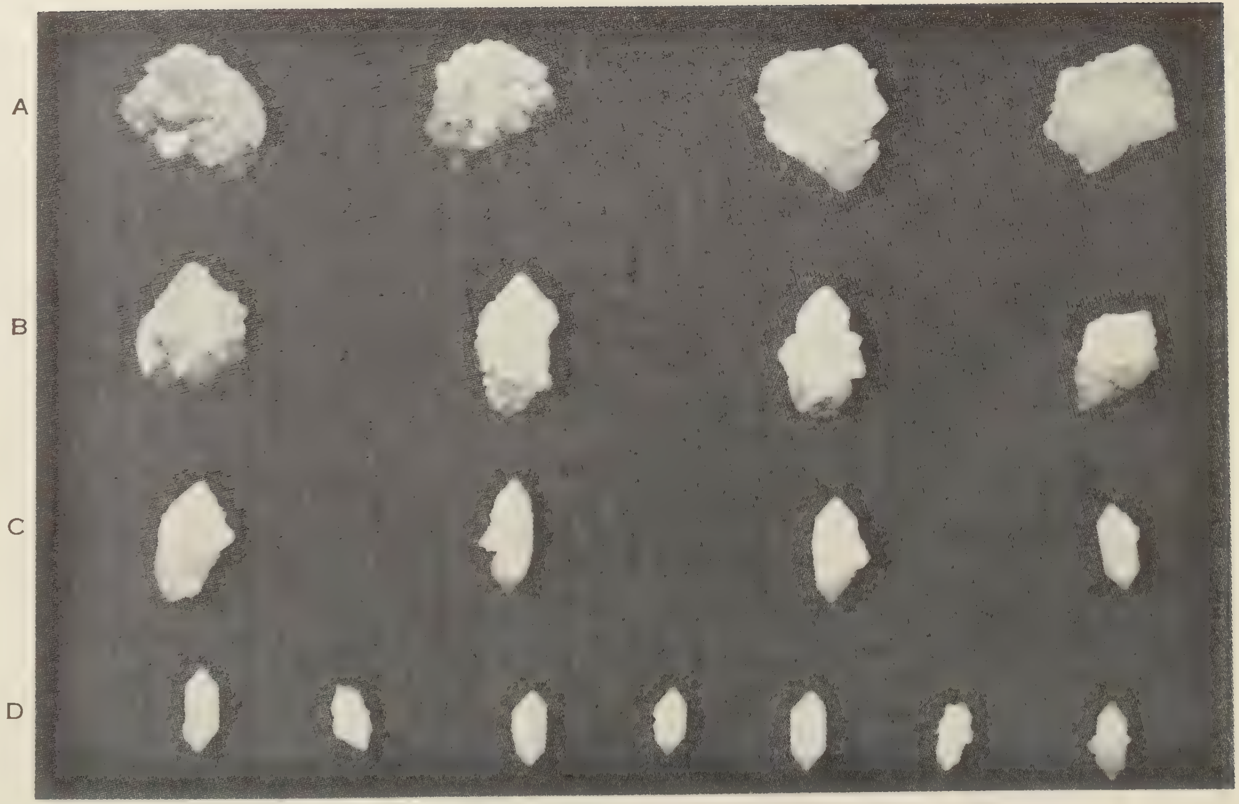

FIG. 1. Quartz crystals from gypsum, Acme, New Mexico. Row A, clusters of crystals. Row B, large crystals with included smaller ones. Row C, crystals with a few included smaller crystals. Row D, series of well developed smaller crystals. Note their symmetry. About natural size.

about 15 millimeters below the surface of the specimen. Beyond this zone isolated crystals, up to a centimeter in length, occur. Between this zone and the top, great numbers of small crystals are found.

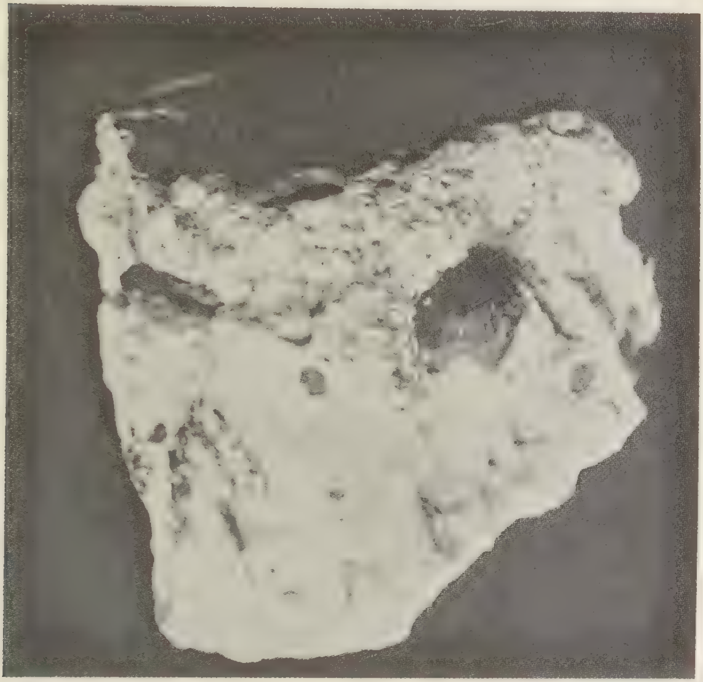

FIG. 2

Massive gypsum from near Acme, New Mexico, showing large clusters of crystals (row A, fig. 1) as well as individual crystals. Note the large clusters are near the top of the specimen. Numerous small crystals are in the gypsum above the clusters. Three or more prismatic crystals are in the lower part. About natural size.

The intergrown crystals take two predominating forms, one, in which a single crystal predominates and has grown about and included smaller crystals, and the other, in which the crystals are arranged in rude radiating clusters, often with one crystal, somewhat larger than the others. Often twelve or fifteen small single crystals are intergrown or clinging to a single large crystal. In one or two specimens, the crystals extend entirely through each

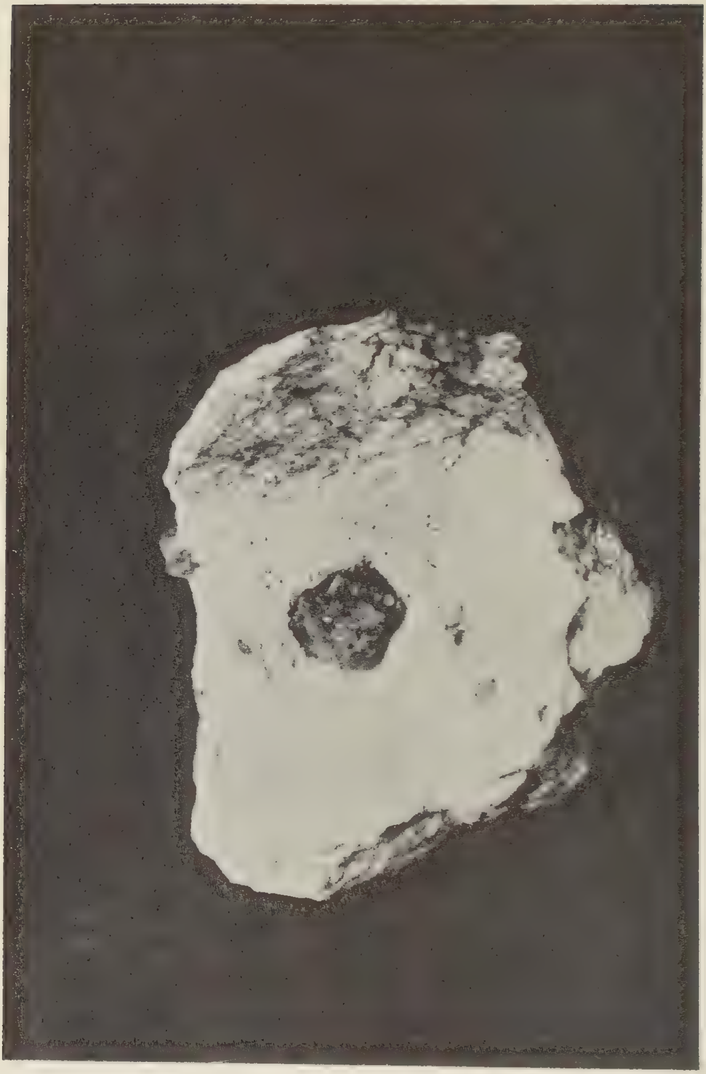

FIG. 3

Another view of figure 2. Note the numerous small crystals in the upper part of the specimen. Nearly natural size.

other. That the larger crystals have grown about the smaller is shown by the smaller size of that portion of the crystal within the larger. Most of the crystals are quite regular in shape but a few taper to the ends, due to incomplete growth. The prismatic faces are rough, due to being incompletely filled out. Although there are a few pits on the rhombohedral faces, they are usually bright and smooth, especially in the case of the plus rhombohedron. There is no regularity in the shape or position of the pits, as they represent the failure of the solutions to completely remove all the inclosing gypsum. Fracture surfaces parallel to *r* were noted on a few crystals. Some of these surfaces were so smooth as to simulate cleavage faces.

The quartz crystals correspond in color to that of the adjacent gypsum. They are dark red in the dark red gypsum near the surface, and become lighter in the lighter colored parts. A considerable difference in color was noted in the clusters, and in single large crystals, where the portion in the dark red gypsum was a deeper red than the part embedded in lighter colored gypsum. The very small crystals are clear and colorless. Those about 2 millimeters long are a light pink in the dark gypsum, the color increasing in intensity as the crystals become larger. Only rarely are crystals 3 to 4 millimeters long a dark color and these are in the darker colored portions

The color is due to included particles of hematite; particles that are residual after the removal of the gypsum. The very small crystals contain few particles, if any at all, and therefore, are colorless, even though they occur in the darker colored gypsum. Hence, both size of the crystal and its position in the gypsum are factors in determining its color. Some of the pits on the surface contain residual grains of hematite.

The crystals are all simple forms: hexagonal prisms, with what appear, at first, to be hexagonal pyramids on each end. The pyramid is actually due to the equal development of the plus rhombohedron *r* and the minus rhombohedron *z*. Not all the crystals show an equal development of the two rhombohedrons but this is a common occurrence. A careful search was made for the trigonal pyramid *s* or the trigonal trapezohedron *x*, but only a doubtful face on a single specimen was found. This face suggested that the crystals were right-handed. Distorted crystals are rare.

Some of the gypsum was dissolved and a considerable number of very small crystals obtained. A little clay, colored by the iron oxide, was the only other insoluble material. A study of these small crystals revealed, splendidly, the sequence in the development of the faces on the crystals. The very minute crystals were the plus rhombohedron *r*, as shown by their high luster. This was the only form on the crystals until they attained a length of 0.15 millimeter, when they had begun to develop the minus rhombohedron *z*. With increase in size, the minus rhombohedron grew faster, and, by the time the crystal was 0.5 millimeter long, both faces was nearly equally developed, resulting in fine small quartzoids. Continued growth produced larger quartzoids, or prismatic faces appeared forming elongated crystals. Subsequent growth was always dominantly on the rhombohedral faces and usually about equal on each. This is shown by essentially al the crystals being doubly terminated prismatic forms.

Near Artesia, New Mexico, where quartz crystals occur in a similar manner, a considerable number of the rhombohedral forms attain a diameter of over a centimeter. This remarkable occurrence is described in a separate paper by Tarr and Lonsdale.

ORIGIN

These quartz crystals are evidently the result of solutions coming from the associated sandstones or possibly shales. The solutions penetrated the gypsum, and by replacing it deposited any silica they were carrying.

The included particles of hematite, the openings occupied by the quartz crystals, and the incompletely developed faces of the crystals, in contact with the gypsum, all point to replacement. The splendid series of crystals, from the simple plus rhombohedron to the final prismatic doubly terminated form likewise point to this later introduction of this quartz. None of the crystals show any evidence of attachment to any object, as they should if they were not formed by replacement.

Although quartz replacing gypsum is not a new type of replacement, the development of such fine doubly terminated crystals by its replacement is unusual. The study reveals, further, the sequence in which the successive faces made their appearance during the growth of the crystal, a fact of some value.

Inasmuch as the divalent calcium in the gypsum molecule is especially active in inducing the coagulation and precipitation of silica (which was undoubtedly transported as a colloid) the more rapid precipitation of the silica as quartz near the surface is explained.

SUMMARY

Quartz crystals, showing the development of the plus and minus rhombohedrons on both ends of the prism, occur replacing massive gypsum at a locality near Acme, New Mexico. The sequence in the development of the various faces on the crystals is readily traced. Silica-bearing solutions entered the gypsum and replaced it by quartz crystals, which are colored by residual hematite from the gypsum.

DIPYRITE AND ASSOCIATED CONTACT MINERALS FROM THE FRANKLIN MOUNTAINS OF TEXAS[1]

John T. Lonsdale, *A.&M. College of Texas.*

The mineral locality reported here is of interest because it contains a large supply of the scapolite mineral dipyrite in an unaltered condition and because the paragenesis of this mineral and associated contact metamorphic minerals is fairly plain. Incidentally the locality constitutes the first recorded occurrence of dipyrite in Texas though collections at the University of Texas contain specimens of scapolites said to be from Texas, but with localities only vaguely given.

The locality here described is on the east flank of the Franklin Mountains in the northwest corner of Section 36, Block 81, El Paso County, Texas, ten miles north and slightly east of the El Paso Post Office. The northwest corner of Section 36 is located on the north side of Fusselman Canyon and the contact minerals are found on the lower south and east slopes of the canyon wall. The locality is reached from the El Paso-Alamagordo highway running north past Fort Bliss. At a point on the road nearly opposite Fusselman Canyon a side road leads to the foot of the mountains near the north side of the canyon. The contact minerals are found a few hundred feet above the point where the road reaches the foot of the mountain and just below a United States Army artillery observation post established on the side of the mountain.

The Franklin Range is a narrow northwestward trending highland some 3,000 feet above flanking plains. The geologic column includes metamorphic and sedimentary formations from pre-Cambrian to Carboniferous age, consisting of quartzites, sandstones and limestones. Igneous rocks of at least three ages are also present. These include rhyolite porphyry, granite, syenite porphyry, andesite porphyry, and basic dikes. The structure is complex, but in general the entire series of rocks, both igneous and sedimentary, is sharply tilted to the westward and broken by numerous faults resulting in steep cliffs and escarpments on the east side of the mountains with excellent exposures of the rocks. The geology of the El Paso quadrangle has been described by Richardson[2] to whose report the reader is referred for further details of the general geology.

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[1] Published by permission of the Bureau of Economic Geology, University of Texas.

At the mineral locality a red granite is the most abundant rock, forming the base of the mountains and the north wall of Fusselman Canyon. The granite, according to Richardson, is post-Carboniferous in age and intrudes the sedimentary series of the region. Richardson, however, did not note contact metamorphic minerals which furnish additional evidence that the granite intruded the sedimentary rocks. The rock contains microperthite, acidic oligoclase, quartz and a little biotite and hornblende. A partial analysis is given below.[3]

SiO_2	73.76
CaO	0.81
K_2O	5.66
Na_2O	3.64

The contact of the granite with the sedimentary rocks is exposed on the north side of Fusselman Canyon. Quartzite and limestone are the intruded rocks and these dipping steeply westward have been sharply cut off along the strike by the granite. The contact is irregular, there being embayments in the limestone and in addition small isolated blocks of altered limestone are engulfed in granite. At the margin of areas of limestone nearly surrounded by granite, and in the engulfed blocks of limestone, dipyrite and other contact minerals are found.

The limestone in contact with the granite is gray, massive and dolomitic containing large quantities of chert and in some places is also arenaceous. The chert forms nearly continuous beds from a fraction of an inch to several inches in thickness. The limestone at a considerable distance from the granite has been changed to a medium grained marble containing scattered grains of olivine. Blocks of limestone a few feet long, engulfed in granite, have been changed to aggregates of metamorphic minerals and near the contact of the main mass of limestone a narrow zone of the same minerals is found. In the latter occurrence the development of silicate minerals is not confined to the original limits of the limestone, but extends also into the margin of the granite. The metamorphism was somewhat irregular, apparently, being selective in nature. The zone found at the contact of granite and limestone where the alteration has been most profound is about 25 feet wide, but can be traced at this place less than 100 feet along the contact, due partly, to poor exposures. In other parts of the locality similar, but small exposures are found, but these will not be described in detail. In the main zone scapolite has been abundantly developed, even cherty layers of the limestone being replaced to some extent by the silicate. In the engulfed blocks of limestone a complete change to silicates occurred, but again selectively since some blocks are practically all garnet, while others are all diopside. In none of these isolated blocks of metamorphosed limestone is scapolite developed to any extent, it being confined to the zone at the contact of granite and the main mass of limestone. The formation of garnet and diopside extended to a greater distance from the granite than did the formation of scapolite, the latter being confined practically to the zone of 25 feet at the contact while the former are found, microscopically at least, in some cases 100 feet or more from the contact.

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[2] Richardson, G. B., *Geol. Atlas of the U. S., El Paso Folio*, No. **166, 1909.**

[3] Richardson, G. B. *Op. cit.*, p. 7.

Veins and dikes are practically lacking at the border of the granite. One small dike a few inches wide cuts the sedimentary series. It is grayish white in color and consists of microperthite, microcline microperthite and orthoclase graphically intergrown with quartz. It is apparently the only representative of the pegmatite stage present. One fluorite lens or vein a few inches long was found cutting the mass of diopside rock. With the fluorite was some feldspar and calcite. The sedimentary series contains dikes of basic igneous rock older than the granite. In the metamorphism these were relatively unaffected, even less so than the chert layers of the limestone.

The minerals found at the locality are dipyrite, garnet, diopside, microperthite, microcline, fluorite, titanite, muscovite and olivine. Ore minerals are practically lacking only a few grains of pyrite being observed and these were found in the marble some distance from the actual contact.

Dipyrite is the principal mineral of the main metamorphic zone mentioned above. It occupies an area which represents original limestone and granite having to some extent at least replaced both. Where the scapolite penetrates granite, thin sections show that it crystallized contemporaneously with some of the granite minerals. Accompanying the scapolite are small amounts of garnet, diopside, calcite and microperthite. All of these are younger than the dipyrite and the feldspar is apparently a second generation mineral. It seems apparent that the dipyrite is more closely related to the granite in origin than such minerals as garnet and diopside. Probably the assimilation of limestone by the magma is involved to some extent. The scapolite not only replaced pure limestone, but the cherty layers as well.

The mineral is light grayish blue in color in fresh specimens and dirty gray on weathered surfaces. It occurs in roughly radiating groups and bundles of vertically striated, long bladed crystals without crystal faces. Individual blades or plates are as much as 10 inches in length. Optically the mineral is uniaxial negative with $\epsilon=1.543$, $\omega=1.553$; $\omega-\epsilon=0.010$. The cleavage is prismatic, excellent to perfect. A complete chemical analysis is not available but chemical and optical data at hand indicate the scapolite dipyrite corresponding to $Ma_{70}Me_{30}$ according to the definition of this mineral given by Winchell.[4]

Garnet next to scapolite is the most abundant mineral found at the locality. It replaces blocks of limestone to the exclusion of other silicates and is sparingly present in scapolite aggregates, replacing the latter. It has also to some extent replaced cherty layers of the limestone. In the scapolite masses the garnet occurs as small grains or masses sometimes with poorly developed crystal outlines. In the direct replacements of limestone, massive beds or bands of the mineral are found. These generally preserve the original bedding of the limestone, but also show banding apparently controlled by the crystal habit of garnet. A few poorly developed crystals are found showing the rhombic dodecahedron alone or combined with the tetragonal trisoctahedron. The mineral is brown in color and is probably grossularite.

Diopside occurs, as has already been indicated, associated with dipyrite and garnet and also alone where it has replaced isolated blocks of limestone. It occupies interstitial space in dipyrite aggregates and replaces this mineral. It also replaces garnet. At one point scapolite replacing a cherty layer of the limestone has been literally peppered with grains of diopside resulting in a very striking rock. It was one of the last minerals to form and is accompanied by feldspar. The diopside is monoclinic, biaxial positive. $Z\wedge C=41°$. $\alpha=1.680$, $\beta=1.690$ and $\gamma=1.705$; all $\pm .005$; $\gamma\text{-}\alpha=.025$ approximately. These data indicate a diopside relatively poor in iron.

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[4] Winchell, A. N., *Elements of Optical Mineralogy*, Pt. II, p. 346, 1927.

Two generations of feldspar are thought to be present in this mineral assemblage. One is closely associated with dipyrite crystallizing contemporaneously with the earliest scapolite formed. The other belongs to the same general time as the diopside, replacing scapolite and the earlier feldspar. The earliest feldspar consists of microperthite and oligoclase and possibly microcline microperthite. The oligoclase is somewhat noticeable in amount. The later feldspar consists of microperthite and microcline with a virtual absence of oligoclase.

Olivine is found only in the marble either at a considerable distance from the contact or in closer areas of the rock which escaped extensive replacement by the other silicates. It occurs as minute grains in the marble constituting about five per cent of the mass. The resulting rock is much like the forsterite marble from Skye figured in many textbooks. The olivine is biaxial positive, with relatively low birefringence and is in the forsterite end of the forsterite-fayalite series.

Muscovite occurs to a very limited extent in the locality. An occasional flake is found in the scapolite specimens and it is probably related to the last part of the mineralization along with feldspar. In the marble some distance from the contact an occasional flake is seen in thin sections. Here the mineral is always in contact with olivine and often embayed by it.

Titanite is present in only small amounts but is related to the other silicates in origin. It occurs in the aggregates of silicate minerals being one of the last to form probably along with or just after diopside. Minute perfect crystals of the mineral were observed in thin sections associated with diopside and in a cavity in the garnet rock, this mineral along with diopside and feldspar was seen in grains 4 mm. in size.

Calcite occurs in the marble as a recrystallization product and as an interstitial material in the aggregates of silicate minerals. In the latter occurrence this mineral evidently took part in the mineralization and was the last mineral to form. It occupies open spaces between blades of scapolite and grains of the other silicates. It also to a limited extent is present as an alteration of diopside, and in this case is thought to be later than the interstitial calcite found in the silicate minerals. Much of the calcite is dark bluish gray in color. In size it varies from minute grains to veins and irregular masses an inch wide.

Fluorite in this assemblage of minerals is unrelated to the contact metamorphism. It occurs with calcite and feldspar in lenses a few inches long, cutting the metamorphosed sediments. The mineral is deep purple in color and is present in grains up to 1 cm. in size. It is to be ascribed to mineralizing agencies active later than the contact metamorphism and possibly of a pneumatolytic nature.

It is thought that the sequence of events in the formation of these metamorphic minerals was as is stated below. The relations of all of the minerals to each other cannot be stated but the major part of the sequence seems well established with the possible exception that overlap existed in the periods of crystallization.

1. Solidification of the granite the later stages of which were accompanied by the formation of dipyrite, since this mineral overlaps some of the minerals of the igneous rock. Apparently limestone was digested by the granite magma since the main scapolite zone definitely penetrates boundaries of both limestone and granite. The dipyrite is thus a mineral closely related in origin to igneous conditions rather than one formed by mobile solutions some distance from the igneous mass. With the final phase of crystallization of the granite scapolite replaced the limestone and even arenaceous beds so that dipyrite became the chief mineral of a zone about twenty-five feet wide.

2. Formation of garnet at the expense of scapolite and limestone. In general the area affected by this mineral is beyond the dipyrite, although throughout the latter small amounts of garnet occur replacing the dipyrite. The metamorphism of the various sedimentary beds was selective for there are blocks of garnet within the granite containing no scapolite as is the case also with blocks consisting chiefly of diopside

3. Replacement and filling of interstices of scapolite, garnet and sedimentary rocks by diopside, feldspar and titanite. This is shown in the scapolite zone proper and in rocks where only garnet and diopside of the silicates are found. The feldspar of this stage seems to be of a later generation.

4. Filling of available space by residual calcite.

5. Injection of the pegmatite dike and of the fluorite veins or lenses.

The place of olivine in this series is not known. It occurs in the marble. If it formed early in the sequence and was replaced by other silicates no remnants are left to give a hint of the event. Its presence may be due to selective action alone. The same statements are true of the mica accompanying the olivine.

The formation of this zone of silicate minerals involves the addition of soda for the formation of scapolite, of alumina for scapolite feldspar and garnet, of iron for the garnet and diopside, and possibly silica for all of the silicates, although there is an abundance of this material in the limestone. Potash was also added being present in the scapolite, feldspar and mica. The metamorphic zone is small and discontinuous but it furnishes a good illustration of this type of metamorphism. The dipyrite is of particular interest. It is a mineral known to be a primary constituent of certain rare igneous rocks and present in many contact metamorphic deposits. Here it marks the transition from granite to contact silicates, being partly pyrogenetic in its association and partly truly contact metamorphic. It may be that this mineral generally has such paragenetic relations.

NOTES AND NEWS

FLUORESCENCE OF MINERALS IN ULTRA-VIOLET RAYS*

L. J. SPENCER, *Keeper of Minerals in the British Museum.*

Certain crystals of fluorspar (fluor or fluorite), especially the twinned cubes from the lead mines of Weardale in County Durham, England, display different colors when viewed from different points of view. The color as seen varies according to the relative positions of the source of light, the specimen, and the eye of the observer. When the crystal is between the source of light and the eye one color is seen, and when the eye is between the crystal and the source of light another color appears. The difference depends on whether the crystal is viewed by transmitted or by reflected (scattered) light. Holding a clear transparent crystal up to the window, the color seen may be pale shades of brown, pink, green (in some crystals a good emerald-green), or colorless; these colors being usually arranged in alternating layers parallel to the cube faces of the crystal. But when the same crystal is viewed by reflected light, with the back of the observer towards the window, a totally different color is seen. This appears, especially in direct sunlight, as a rich bluish-violet glow or shimmer diffused over the surface of the crystal, very much like the bloom on a ripe plum. When a lens is held in front of the crystal, a conical beam of sunlight inside the crystal is traced out by this color.

White light, such as sunlight, may be resolved into its component colors by various methods. Everybody knows the colors of the rainbow and the "prismatic colors" produced when light passes through a prism (such as the bevelled edge of a mirror)—red, orange, yellow, green, blue, indigo, violet. These colors are the expression of the differences in wave-length, which are successively shorter from red to violet. The spectrum of sunlight is, however, not confined to the rays visible to the eye. Beyond the red we have the infra-red, these being heat-rays of longer wave-length; and beyond the violet the ultra-violet—chemically active rays of shorter wave-length.

Now if we place a small crystal of fluorspar in the red part of the spectrum of sunlight nothing remarkable happens, but when it is moved up to the violet end it begins to glow with a bluish-violet color; and this glow becomes more intense when the crystal is moved farther on into the invisible ultra-violet. The crystal possesses the curious property of absorbing the invisible rays of shorter wave-length and giving out in their stead visible rays of longer wave-length. It is, in fact, acting as a transformer of the wave-length. Just how this happens we do not know. A learned discussion with mathematical treatment of the relation between the ether vibrations of light and the orbits of electrons would be out of place in this magazine.

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* This article appeared in the *Natural History Magazine*, issued by the British Museum, October 1928, vol. 1, pp. 291–298; but as this magazine does not reach many American readers the article is reprinted in this Journal with the author's permission. Attention is especially called to the description of an exhibition case to illustrate the fluorescence of minerals in ultra-violet light which has attracted wide attention. Editor.

This interesting phenomenon, shown *par excellence* by fluorspar, was termed fluorescence (from analogy to opalescence) by Sir George Gabriel Stokes[1] in 1852. It had been first investigated by Sir David Brewster in 1834 to 1848 and by Sir John Herschel in 1845, and was also studied by Dr. John Hall Gladstone[2] in 1855. But it still remains a puzzle, although voluminous treatises have been written on the subject by German physicists.

An important point to bear in mind is that a fluorescing body is self-luminous and, like a glow-worm, it is a source of light. This "cold light" is the most efficient form of lighting, for there is no accompanying waste of energy in the production of unwanted heat. It is the lighting of the future.[3] Now-a-days, for example, we strike a match for two totally different purposes—to shine a light or to light a fire. In one case we want light and in the other heat, so we use one and waste the other. Further, the fluorescent color emanates from the body itself; it is not a selective color depending on the nature of the outside illumination. (A rose that is red in white light will be black in green light).

Fluorescence is shown directly in ordinary light by comparatively few substances. Besides fluorspar, we have the mineral-oils (petroleum), including their separation products, paraffin-oil (kerosene) and the heavy lubricating and engine oils, which, as is well known, display blue and green colors on the surface by reflected light. It is also well shown by certain aniline dyes, such as fluorescein and eosin, and by uranium-glass. Usually, however, for most substances the fluorescence is masked by the daylight. The phenomenon is shown to the best advantage in a dark room and using only the dark ultra-violet rays to excite the new radiations. High-tension electric sparks are rich in ultra-violet rays. Sir George Stokes made use of lightning in some of his experiments on fluorescence, but he found that this was not easy to control. Striking results may be obtained with a Ruhmkorff coil or a small transformer stepping up to 4000 volts and sparking between iron terminals. But the most convenient and efficient source of ultra-violet rays is the silica-glass mercury-vapor lamp, which is now much used for the production of "artificial sunlight." A screen of a special kind of dark glass cuts out all the visible rays of light and allows only the ultra-violet rays to pass out of the apparatus.

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[1] In 1892 at Cambridge I was fortunately able to attend a short course of lectures on fluorescence given by Sir George Stokes. His experiments, with the simplest and most primitive of apparatus, were performed in a beam of sunlight admitted through a slit in a shuttered window. For each experiment it was necessary to wind down the heavy shutter and each time solemnly to wind it up again. He continued to talk in his feeble voice while grinding away at the winch-handle of the creaking rack and pinion, with the result that very little was heard of his lectures. When I offered to help the feeble old man in this laborious operation I was severely told "Young man, keep your place."

[2] Some of Dr. Gladstone's original materials were sent to me by his daughter, Miss Florence M. Gladstone, only a fortnight before her death in July, 1928.

[3] Fluorescence may be excited by several different methods. The radioactive method by mixing a radium salt with a luminous paint is much used for watch dials. The method with a mercury-vapor lamp, although very convenient for experimental purposes and for a small display, would be very wasteful economically for lighting on a large scale.

While on a visit in 1924 to the famous mineral locality of Franklin Furnace in New Jersey I was much interested in a simple method used by the New Jersey Zinc Company for the quick detection of willemite (zinc silicate), which is an abundant mineral in the zinc ores at that locality. In several of the laboratories and offices there was fixed to the wall in a dark corner a small apparatus giving a high-tension spark which could be switched on from the lighting circuit. A piece of ore held beneath the spark showed up any willemite present by a vivid green fluorescence. Some very pretty effects were obtained; for example, specks of pale green willemite embedded in snow-white calcite glowed as brilliant green spots in a crimson background. This simple test I thought might be applied to the zinc ores of Broken Hill in Northern Rhodesia. In these mines there are large quantities (over 100,000 tons) of a peculiar "yellow rock" or "yellow waste" carrying up to 33 per cent of zinc oxide, which had never been completely determined mineralogically, although in 1908 I had detected in it some obscure crystals of willemite. These minute crystals when exposed to the ultra-violet rays showed a bright yellow fluorescence, quite different from the brilliant green of the Franklin Furnace willemite. Trying willemites from other localities I found that, while some showed a bright yellow or a dull dark-green fluorescence, most of them showed none at all. Even certain types of willemite from Franklin Furnace were found to be unresponsive.

I was therefore forced to the conclusion that fluorescence in ultra-violet rays is not a sure test for willemite, and I very soon found that the same applies to other minerals. Some specimens of fluorspar show no fluorescence, and this is the case with the single specimen of the Derbyshire "blue John" that I have tried, although I have been told that this variety of fluorspar shows it to perfection. Thinking that the fluorescence might be due to traces of coloring matter present in the mineral, some small perfectly colorless and water-clear crystals of fluorspar from the iron mines of west Cumberland were tried: these displayed a very rich and deep violet fluorescence. On the other hand, some dark-colored specimens from other localities showed no fluorescence.

A set of twenty-three small crystals of diamond from British Guiana, selected to show the range in color and the inclusions in the crystals, was tested in ultra-violet rays. A yellow-green octahedron gave a brilliant fluorescence of the same color, three colorless crystals showed up a good blue, and the rest were unresponsive. Different varieties and specimens of the mineral species corundum also gave varying results. Red gem corundum (ruby) shows a wonderful scarlet glow, and the stone appears to be surrounded by a halo. Exactly the same effect is shown by the artificially made rubies, and also by red spinel of gem quality. Yellow gem corundum gives an orange-yellow fluorescence, but the blue sapphire and the amethystine, green, and colorless gem varieties of corundum are unresponsive. Opals also are capricious. Only the purest of all opals, the colorless and water-clear "hyalite," was found to respond. Specimens from Mexico and from the Kaiserstuhl in Baden gave out a soft sap-green light; but similar specimens from other localities refused to act.

These few examples serve to indicate that extremely variable results are obtained, and it is therefore not surprising that there are many contradictory statements in the literature. Many writers have remarked on the fact that they were unable to obtain the results recorded by previous observers; and indeed in some cases the same experimenter has not always been able to repeat his own results, probably because he was not using the same materials and under exactly the same conditions. The early workers[4] were placed at a disadvantage in having only the inconstant sunlight at their disposal. Depending on the time of day or of year, sunlight has to traverse different thicknesses of the atmosphere, and consequently the absorption of the ultra-violet varies and in foggy weather is practically complete. (For this reason a patient for ultra-violet treatment is sent to the mountains rather than to the seaside). The fluorescence of any particular substance is evidently excited by ultra-rays of a certain wave-length or over a certain range of wave-lengths; and unless just the right kind of rays are present no fluorescence is produced. Several writers have given glowing accounts of the behaviour of the mineral pectolite in the ultra-violet rays. I myself have tried various forms of pectolite from different localities, but always with negative results. Again, I read in a book that æsculin gives a brilliant fluorescence; but the sample that I obtained refused to act (perhaps because it was labelled "esculine"—indicating that it was an old preparation). However, with a new preparation of æsculin, obtained simply by pouring boiling water on horse-chestnut twigs, the tea-colored extract showed a beautiful turquoise-blue fluorescence in the ultra-violet.

The selection of suitable materials, or rather of individual specimens, is thus quite haphazard. The majority of my trials have been complete failures. A possible method would be to go round the Mineral Gallery on a dark night with a portable ultra-violet apparatus, and so pick out those specimens which are possessed of the whim to glow up. But quite likely by the morning they would have changed their minds and then refuse to function. Time could scarcely be a factor, but they may be influenced by light, differences of temperature, humidity of the atmosphere, or even by the countless "wireless" waves of all manner of wave-lengths that now permeate everywhere. It would indeed be interesting to find a mineral, or crystal. that fluoresces to, say, "2LO."

Almost without exception fluorescent substances are transparent or at least translucent to light. It appears to be necessary that the rays should penetrate the substance to a certain distance for the effect to be produced. The most remarkable result that I have obtained is with a black opaque specimen of zinc-blende from Tsumeb in South-West Africa. It is a piece of massive granular zinc ore looking much like a lump of coal. This was tried because it shows in a very striking manner the allied phenomenon of triboluminescence (luminescence by rubbing): when it is lightly scratched with a knife-blade it gives streaks of yellow sparks. In the ultra-violet rays it glows with a brilliant fiery yellow like a live coal. When the specimen is lightly touched with the finger the merest invisible trace of the substance is picked up, but sufficient to give a good glow. Zinc-blende is quite a common mineral, but only certain specimens from Tsumeb and a pale-colored variety from Beaver County, Utah, have been found to show the fluorescent glow.

Some substances fluoresce only in the solid state, others only in the liquid state or in solution, whereas the metal sodium fluoresces in the gaseous state. Other substances show up only when their solution is painted on white paper or when used as dyes on fabrics. Often also the presence of some other substance is necessary. Artificially prepared willemite (zinc silicate) shows no fluorescence when chemically pure; but the property is strongly brought out by the addition of a small amount of manganese. (This explains the fluorescence of the Franklin Furnace willemite; but why crystals of willemite found embedded in black manganese ore at the Sable Antelope mine in Northern Rhodesia fail to fluoresce, I cannot understand). The various salts of quinine display their remarkable fluorescence to advantage only in the presence of free acid, the merest trace being sufficient. Many other vegetable alkaloids give strange results, and under the right conditions it is possible to detect the presence of some of these in one part in a thousand million. The behaviour of the wide range of plant products in ultra-violet rays would no doubt afford an even more fascinating study than mere minerals. It was in the alcoholic extract from laurel leaves that Sir David Brewster first discovered in 1834 the phenomenon of fluorescence. A freshly prepared clear leaf-green solution of chlorophyll is remarkable in showing a deep blood-red fluorescence in the ultra-violet (and curiously, the same red color is seen by transmitted light through thicker layers of the solution, but this is a quite distinct phenomenon known as dichromatism).

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[4] My own tests have been made under what I believe to be more constant conditions, using a Hanovia silica-glass mercury-vapor lamp at 1 ampère and 220 volts, with a dark glass screen passing ultra-violet rays of wave-lengths about 390 to 310$\mu\mu$. These longer ultra-violet rays can pass through several layers of glass, but I have made no quantitative measurements.

An exhibition case to illustrate the fluorescence of minerals (and some other substances) in ultra-violet rays has been fitted up in one of the wall-cases in the corridor at the entrance to the Mineral Gallery of the Natural History Museum at South Kensington, London. This is probably the first public exhibit of the kind, and during the August Bank Holiday week it attracted thousands of visitors. Marvellous changes in color effects are produced by simply pressing a button outside the case. The specimens are first seen in ordinary light with inside electric lighting ("linolight"). When the button of the two-way switch is pressed, this changes over to ultra-violet rays, which are produced by a Hanovia "artificial sunlight" mercury-vapor lamp fitted with a dark screen to cut out all the visible light rays, allowing only the dark ultra-violet to fall on the specimens. Large groups of fluorspar crystals shine up with a wonderful bluish-violet glow, willemite and autunite with a brilliant green, zinc-blende with a golden yellow, white calcite with a rose-red, etc. When the spring-switch is released this fairyland of glowing colors suddenly vanishes.

The case has been painted with a dark grey background, care being taken to avoid a fluorescent paint. Labels for each specimen have been painted with a white fluorescent paint (zinc white) on dark grey card, and these are easily read in the two illuminations. Even in the lighted corridor the effect is very striking; but of course still better results would be obtained in a dark room, though this would be less suitable for public exhibition.

Chemically germanium is closely related to tin and Prof. Papish of Cornell University has detected this element in nearly all cassiterites examined but it is present only in traces. The search for germanium is being extended to a number of minerals occurring in pegmatites and veins. Thirty-four specimens of topaz, examined spectrographically, from twenty-seven different localities were found to contain germanium. Topaz from Schneckenstein, Saxony, and from Zinwald, Bohemia, contained only traces but the majority of specimens from other localities showed quite a number of spectral lines of the element. Prof. Papish is now engaged in attempting a *quantitative* determination of germanium in topaz.

Dr. W. F. Foshag, of the division of mineralogy of the U. S. National Museum, has been made a corresponding member of the Sociedad Científica "Antonio Alzate" of Mexico.

The Roebling collection of the National Museum has acquired by purchase an unusual platinum nugget from the Choco district, Colombia. It weighs 17¼ troy ounces and shows associated chromite in numerous places on its surface.

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Minutes of the November Meeting

A regular monthly meeting of the New York Mineralogical Club was held at the American Museum of Natural History on the evening of November 21, 1928, under the chairmanship of the president, Dr. Herbert P. Whitlock. About forty-five members and visitors attended.

Messrs. William P. Hewitt, J. P. H. Marker, and Leo H. Norodny of New York City, Mr. R. C. Neuendorffer of North Tarrytown, N. Y., Col. William Boyce Thompson of Yonkers, N. Y., and Mr. E. C. Doremus of Boonton, N. J., were elected to membership.

Mr. Morton reported a successful Club excursion to the quarries at Paterson, N. J., on Election Day, Nov. 6th. Over thirty persons attended and about twenty different mineral species were found.

The Club was then addressed by Mr. Wilbur G. Valentine, of Columbia University, on *The New Ore Body at Cananea, Mexico.* This ore deposit is interesting for its peculiar crucible shape and zoned structure. The principal minerals are bornite, chalcopyrite, molybdenite, pyrite, and quartz. The deposit occurs in a quartz-porphyry intrusive into volcanic rocks. It is apparently entirely unconnected with any feeder or channel of supply from below.

The origin of the ore body is very obscure. It has been ascribed to magmatic differentiation and also to deposition from solutions after the formation of the quartz-porphyry. Objections to both theories were presented. Sinking of the surface has also been invoked by Locke to account for the unusual shape.

The lecture was illustrated by lantern slides and by a large number of specimens of the ore. In addition to these exhibits a specimen showing parallel crystals of rose quartz from Bedford, N. Y., was displayed by Mr. Weidhaas.

Horace R. Blank, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, November 1, 1928

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Trudell, in the chair. Twenty-seven members and twenty visitors were present. The name of Mr. Charles M. B. Cadwalader was presented for active membership.

Dr. William S. Newcomet addressed the society on the *Fluorescence of minerals by radium.* The effect of radium emanations on specimens of calcite, aragonite, celestite, gypsum, fluorite, and willemite was demonstrated. Very marked was the luminescence shown by some specimens of these minerals in the dark after exposure to an ordinary electric light bulb. Mr. J. C. Boyle contrasted the fluorescence of willemite and calcium-larsenite from Franklin, New Jersey, by means of an iron arc.

Dr. Newcomet described a trip to Yellowstone Park, illustrating his remarks with colored moving pictures. Mr. Toothaker spoke briefly of his recent visit to some Cuban iron mines. Mr. Squiers reported on a trip to Paterson with Mr. Dippel. Mr. Wolf spoke briefly on the Gap nickel mine, where he found some annabergite, pyroxene, and pyrrhotite. Mr. Strock described visits to the Chester Springs graphite mine, Leiper's quarry, and Mineral Hill.

SAMUEL G. GORDON, *Secretary*

NEWARK MINERALOGICAL SOCIETY

The members of the Newark Mineralogical Society held their 101st. business meeting Sunday afternoon, in the rooms of the Newark Technical School on High Street.

The president, Daniel T. O'Connell, presided during the meeting. Routine business was transacted, followed by the annual election of officers and trustees.

The election resulted as follows:

President—William H. Broadwell, of Newark.
Vice-president—John A. Grenzig, of Brooklyn.
Secretary—Rodney B. Miller, of Newark.
Treasurer—Herman M. Lehman, of Newark.

Mr. Grenzig and Mr. Lehman were re-elected. Mr. Broadwell was promoted from the office of Secretary, which he has held since the formation of the society in 1915. The new president is an enthusiastic mineralogist and has a very fine collection of New Jersey minerals, which is especially rich in Franklin material.

The Board of Trustees was completed by the election of former Presidents Paul Walther of Elizabeth and Herbert L. Thowless of Newark. The board consists of the four principal officers and three elected at large. The present board consists of:

William H. Broadwell, of Newark, term expires November 1929.
John A. Grenzig, of Brooklyn, term expires November 1929.
Rodney B. Miller, of Newark, term expires November 1929.
Herman M. Lehman, of Newark, term expires November 1929.
Charles W. Hoadley, of Englewood, term expires November 1929.
Herbert L. Thowless, of Newark, term expires November 1930.
Paul Walther, of Elizabeth, term expires November 1931.

The new president was escorted to the chair and assumed his duties. His first official act was to announce the following committees.

Membership: Herbert L. Thowless, *Chairman*
John A. Grenzig
George E. Carpenter
Miss Josephine Morlock
Richard P. Milburn

Outings: John A. Grenzig, *Chairman*
Charles W. Hoadley
Louis Reamer
Publicity: Herbert L. Thowless.

The members of the program committee will be announced at the December meeting.

Former president O'Connell will address the December meeting on *Magnetic and Electrical Characters of Minerals.* This address will be illustrated by means of experiments. The president requested members to bring suitable specimens to the meeting and to all meetings in the future.

After all business had been completed a symposium was held on the general subject *Minerals collected during vacation.* A talk was given by Mr. Hoadley of a collecting trip taken near Montreal, Canada. Short talks were also given and minerals exhibited by George E. Carpenter; Paul Walther; W. Dan Quattlebaum; Louis Reamer and others.

President Broadwell told of the difficulty in arranging suitable and profitable outdoor trips on account of the many quarries and other collecting places being abandoned. The new outing committee will take in hand the entire matter of trips and try and arrange for several in the future.

The principal of Public School No. 36 of Brooklyn has asked the society to provide material for its museum.

The next business meeting will be on Sunday afternoon, December 2nd. All mineralogists and students are cordially invited to the meetings.

HERBERT L. THOWLESS, *Chairman of Publicity Committee*

THE MINERALOGICAL SOCIETY (ENGLAND)

Mineralogical Society, November 6, 1928. Dr. G. T. Prior, President, in the chair.

MR. F. A. BANNISTER: *The so-called "thermokalite" and the existence of sodium bicarbonate as a mineral.* The composition of a large collection of saline incrustations collected by Dr. Johnston-Lavis about 1889, has been investigated. He labelled them "thermokalite" but they are found to be a mixture of trona, thermonatrite, thenardite, and free sodium bicarbonate; no potassium salts are present. The name nahcolite is proposed for naturally occurring sodium bicarbonate. These incrustations were found lining the walls of a cuniculus near the Stufe de Nerone, Baia, Naples, Italy; their mode of occurrence is discussed from a physical-chemical point of view.

DR. W. A. WOOSTER: *The piezo-electric effect of diamond.* The effect has been investigated by a delicate method using magnetic attraction to apply pressure to the diamond. The result shows that the effect, if it exists, is less than 1/200th of the effect observed in quartz cut perpendicular to the electric axis.

MR. J. D. BERNAL and NORA MARTIN showed X-ray photographs of the arkansite variety of brookite indicating that the space-group is Q_h^{15}. An explanation was offered of how A. Schröder's observations did not lead to this result.

MR. F. N. ASHCROFT exhibited specimens of minerals collected recently in Switzerland, together with photographs of the localities represented.

W. CAMPBELL SMITH, *General Secretary*

NEW MINERAL NAMES

Klockmannite

Paul Ramdohr: Klockmannit, ein neues natürliches Kupferselenid. (Klockmannite, a new natural copper selenide). *Centr. Mineral.*, Abt. A. No. 7, pp. 225–232, 1928.

Name: In honor of *F. Klockmann*, who collected the selenides of Sierra de Umango and first described umangite.

Chemical Properties: A copper selenide, CuSe. Analysis: Cu 35.37, Se 45.73, Pb 0.84, Ag 0.73, Fe_2O_3 0.74, quartz 1.34, H_2O+ 6.84, H_2O- 0.48. Five other partial analyses are given. (Analyses by Dr. Geilmann on material carrying small amounts of umangite, eucairite, clausthalite, hematite, and strongly altered to chalcomenite).

Physical and Optical Properties: Color slate gray, tarnishing to dark bluish black. Reflection pleochroism strong, from dark olive gray or slate gray to light grayish white. Strongly anisotropic, at 45° the color is white to light rose brown; with immersion cream white to orange rose. Cleavage, probably basal, marked. Hardness <3. Sp. Gr. probably more than 5.

Occurrence: Found as granular aggregates in calcite associated with umangite, clausthalite and eucairite, often strongly altered to malachite and chalcomenite at Sierra de Umango, Argentina. Also in small quantities but widely distributed in the ores of Lerbach and Skrikerum. Probably present in many samples of so-called zorgite.

Discussion: The optical behavior of klockmannite and its basal cleavage suggests that it is isomorphous with covellite.

W. F. Foshag

Kerzinite

N. A. Schadlun: *Nutzbare fossile Rohstoffe Russlands 4.* (Petrograd. **1923.** Nr. 5. Nickel. 7 pp.) Abstr. in *N. Jahrb.*, **1926**, vol. 2, *Abt. A*, p. 113.

Name: In honor of *N. A. Kerzin*, discoveror of the nickel deposits in which the mineral is found.

Chemical Properties: A peat containing nickel silicate. Contains 42% carbon, 6–7% ash. The ash contains 7–15% nickel. Combustible.

Occurrence: At the Nowo-Tscheremschansky mine, Werchne-Ufalei Datscha, Urals, with other ores of nickel, including nickeliferous polianite, siderite, limonite, etc.

W. F. F.

Julienite

Alfred Schoep: Juliëniet, een nieuw Mineral (Julienite, a new mineral). *Natuurwetenschappelijk Tijdschrift*, 10jg., No. 2, pp. 58-9, 1928.

Name: In honor of Henri *Julien*.

Chemical Properties: A chloro-nitrate of cobalt. No analysis given. Soluble in water to a rose colored solution.

Crystallographic Properties: Small needle-like crystals.

Physical and Optical Properties: Color blue. Extinction parallel. Elongation positive. Indices, 1.645 (parallel to the elongation); 1.556 (across elongation).

Occurrence: Found as a thin crust of minute needles on a white, weathered talcose schist containing, also, a black mineral of copper and cobalt.

Discussion: Resembles buttgenbachite but free from copper and nickel. Probably uniaxial.

W. F. F.

ADDITIONAL DATA

Plumboferrite

K. Johansson: Mineralogische Mitteilungen. 2. Über Zusammensetzung und Kristallographie des Plumboferrits. (Mineralogical Contributions. 2. The Chemical Composition and Crystallography of Plumboferrite). *Zeit. Krist.*, **68,** pp. 91–102 (1928).

Chemical Properties: Formula: $PbO \cdot 2Fe_2O_3$. Analysis: PbO 33.03, FeO 0.78, MnO 1.41, CaO 0.40, MgO 0.34, K_2O 0.13, Na_2O 0.17, Fe_2O_3 63.01, Sb_2O_3 0.25, TiO_2 0.08; Insol. 0.15.

Crystallographic Properties: Hexagonal. Habit tabular parallel to the base. $c=3.9719$. $p:c=77°42'$. Forms numerous with very irregular development. $a=11.86$ Å. E. $c=47.14$ Å. E.

W. F F.

DISCREDITED SPECIES

Shannonite

C. E. Tilley: A monticellite-nepheline basalt from Tasmania. A correction to mineral data. *Geol. Mag.*, **65,** pp. 29–30 (1928). Original description: *Geol. Mag.*, **64,** 143–144 (1927). Also Frederick P. Paul: *Tsch. Min. Pet. Mitt.*, **25,** 309–311 (1906).

The optical properties obtained by Paul by calculation are shown by direct measurement to be erroneous. n lies between 1.66 and 1.68. Optically negative with the optic axial angle less than that of olivine. This agrees with monticellite and the analysis of the rock agrees with a composition: nepheline 27 per cent, augite 27, monticellite 27, and olivine 14 per cent. The name shannonite should be dropped.

W. F. F.

Graminite, Pinguite, Hoeferite, Morencite and Müllerite

Esper S. Larsen and George Steiger: Dehydration and Optical Studies of Alunogen, Nontronite and Griffithite. *Am. Jour. Sci.*, **15,** 10–15, 1928.

The water content of nontronite is shown to be very variable. Within the range found are included graminite, pinguite, hoeferite, morencite and müllerite. They are all essentially hydrous ferric silicates of the composition $Fe_2O_3 \cdot 3SiO_2 \cdot nH_2O$.

W. F. F.

Eisenbrucite

Paul Gaubert: *Bull. Soc. Fran. Min.*, **45,** 216-219, 1925.

This mineral, believed to be a ferriferous brucite, is shown to have the following properties: Uniaxial negative (brucite is positive), $\omega=1.564$, $\epsilon=1.548$. Sp. Gr. 2.18–2.22, variable because of inclusions. The original analysis by Peterson suggests a member of the hydrotalcite group. (This analysis is very close to brugnatellite).

W. F. F.